7th Annual International CMP Conference

Tuning Hydroxylamine Slurries for Copper Barrier Polishing for (SiLK^{TM}) Low-k Integration

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It doesn't get any planar than that.^{sm}

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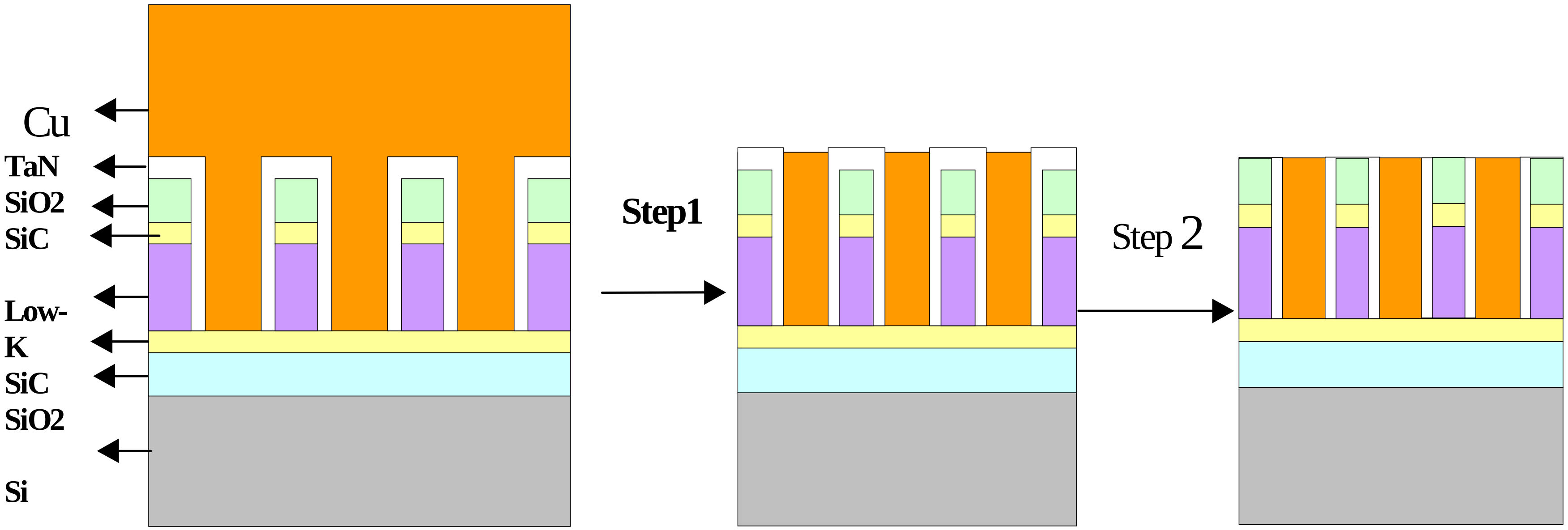
AGENDA

- Introduction
  - * Current Cu/SiLK integration
  - * Cu/SiLK CMP process
  - * Nitrogen-based slurry
- Experimental Set-up
  - * Polisher, pads, measurement equipment, wafers and slurries
- Results
  - *Cu-II barrier slurry (hydroxylamine/silica-based) applications with a. High Selectivity

    b. Low/Non Selectivity

    on Cu/SiLK blanket and patterned wafers
  - * Copper and SiLK surface rms, FTIR, electrical and adhesion data after CMP
- Conclusion

Copper/SiLK Integration and CMP Process



Step 1: Polishing off Cu film and stop at barrier layer

Step 2: Polishing off barrier (Ta/TaN) film and stop at ILD layer

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General Technical Requirements for Cu CMP

Roadmap for advanced Cu developments

	0.18 µm	**0.15 µm**	**0.13 µm (2001)**	**0.1 µm (2003)**	**0.07 µm**
Dishing (100 um pad)	500 Å	350 Å	250 Å	180 Å	120 Å
Erosion (90% density)	700 Å	500 Å	350 Å	200 Å	150 Å
Dielectric loss	300 Å	250 Å	200 Å	150 Å	100 Å
WIWNU (1s)	4%	<3%	<2%	<2%	<2%
WTWNU (1s)	4%	<3%	<2.5%	<2%	<1%
LPD defects	<15 >0.2 µm	<20 >0.16 µm	<30 >0.12 µm	<50 >0.08 µm	<100 >0.05 µm
RR Step 1	>5000 Å/min@5PSI		>5000 Å/min@**2PSI**	>5000 Å/min@**<0.5PSI**	
RR Step 2	>500 Å/min@5PSI		>500 Å/min@**2PSI**	>500 Å/min@**<0.5PSI**	

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ILD Material Requirement in IC

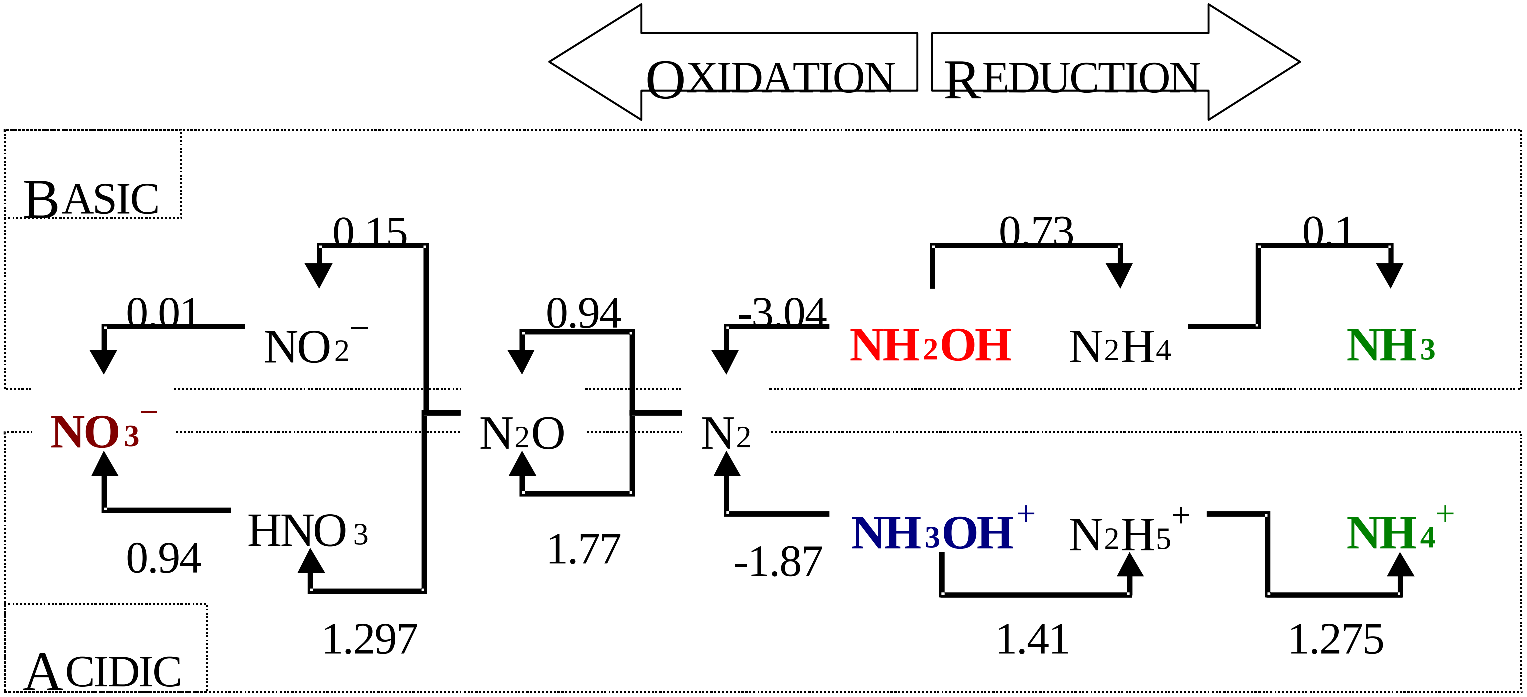
- **Using a low-k dielectric film**
- Exhibit adequate material properties
  - thermal
  - electrical
  - mechanical
- Be able to work with the other materials of the interconnect structure
- Be compatible with to IC process of cleaning, etching, CMP, and thermal treatment
- Be available in high purity form and low cost
- Be able to operate reliably over the life of the product under the specified device operating conditions.

LY-HBstudyILD

SiLK Dielectric Properties

	SiLK	V7	V8	V9
K	2.65	2.35	2.20	2.10
D_{avg} (nm)	NA	25	16	< 9
Modulus (GPa @ 1 um)	3.6	2.8	2.7	2.8
Hardness (GPa @ 1 um)	0.27	0.17	0.16	0.15
CTE	62	62	62	~ 62
Toughness / Adhesion (Mpa-$m^{0.5}$)	> 0.35	> 0.35	> 0.35	> 0.35
Process Temperature (^{o}C)	400 – 450	430	430	400
Chemistry	SiLK	SiLK	SiLK	SiLK

Hydroxylamine
Reduction Potentials & Reaction Paths



Reference: Dr. Srini Raghavan "Copper Removal in
Hydroxylamine Based Slurries" 7th International Symposium

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EKC Current Hydroxylamine-Based Slurries for Copper CMP

	Oxidizer	Abrasive	Application
Cu Phase-I	Hydroxylamine Based	Al_2O_3	Removal Cu layer
Cu Phase-II	Hydroxylamine Based	Colloidal Silica (Supply A)	Removal TaN with a high selectivity
	Hydroxylamine Based	Colloidal Silica (Supply A & B)	Removal Cu, TaN, TEOS at a low selectivity
	Hydroxylamine Based	Abrasive free	Removal TaN with a high selectivity
Single Phase	Hydroxylamine Based	Al_2O_3	Removal Cu, barrier and stop at ILD layer

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Experimental Set-Up

* Polisher: IPEC 472;	
*Polishing Pads:	Rodel IC1000 k-grv/Suba IV and Politex polishing pads
* Measurement Equipment:	Cu and TaN Thickness: CDE ResMap 176
	TEOS Thickness: KLA-Tencor 650
	SiLK Thickness: KLA-Tencor 650 & Gaertner Ellipsometry
	SiLK surface chemical changer: BioRad FT-IR spectrometer Cu Surface roughness: Digital Instrument AFP200
	Cu Dishing & Erosion: KLA-Tencor P2 & DI AFP
*Slurries:	EKC Cu Phase-I with Alumina and oxidizer,
	EKC Cu Phase-II with Silica Abrasives and oxidizers (A to G)
* Blanket Wafers:	200mm EP copper, TaN, TEOS and SiLK: **p-SiLK (includingV9) SiLK-I (regular) SiLK*I (Ensemble)**
* Cu Patterned Wafer:	200mm **Sematech 931, 831, 854 Pattern** **Sematech 800 pattern - CMP2 (Cu/SiLK)**

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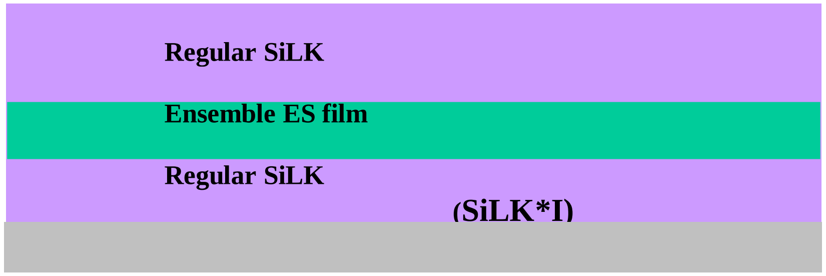
SiLK Blanket Wafer Types

Porous SiLK (V9-LC & V9-HC)

Regular SiLK
(SiLK-I)

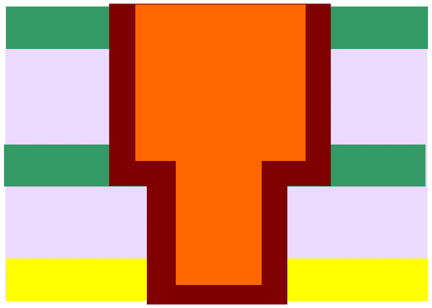


Regular SiLK

Ensemble ES film

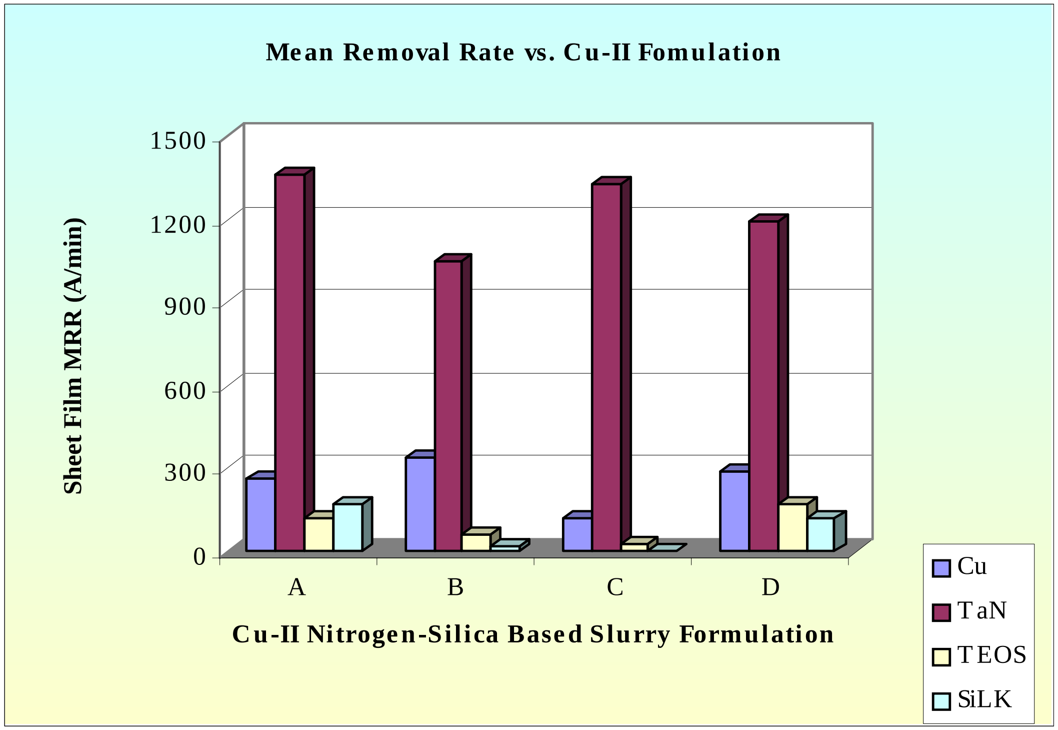
Regular SiLK

(SiLK*I)



SiLK+Ensemble Integrated Stack

Silica Based Slurry for High Barrier Selectivity



Results:

- Selectivity of Cu:TaN:SiLK = 1: 3-11: <1
- TaN removal rate is related to Cu-II oxidizer concentration as expected.
- Reducing either the oxidizer or abrasive will reduce SiLK removal rate.
- Post CMP Rms of Cu and SiLK was 5-10 Å.

Slurry Formulation				Post CMP Rms (A)	
Slurry	Oxidizer	Silica Solids	Abrasive Type	Cu	SiLK
A	50%	5%	Abra-I	7	5
B	20%	5%		10	7
C	50%	1%		9	6
D	50%	5%	Abra-II	7	5

Process:

IPEC 472 Polisher / Politex Embossed Pad

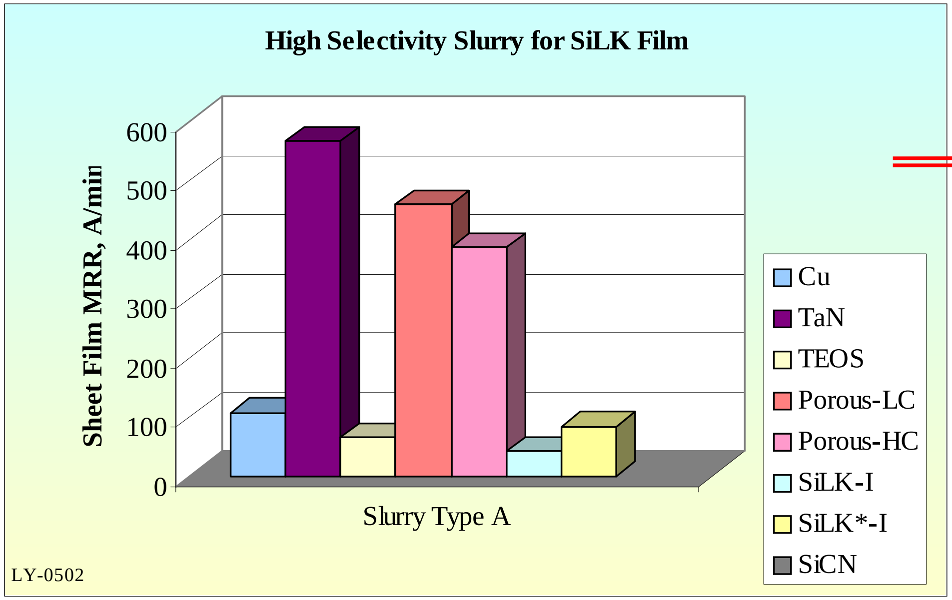
3 psi polishing pressure, 50 rpm platen speed

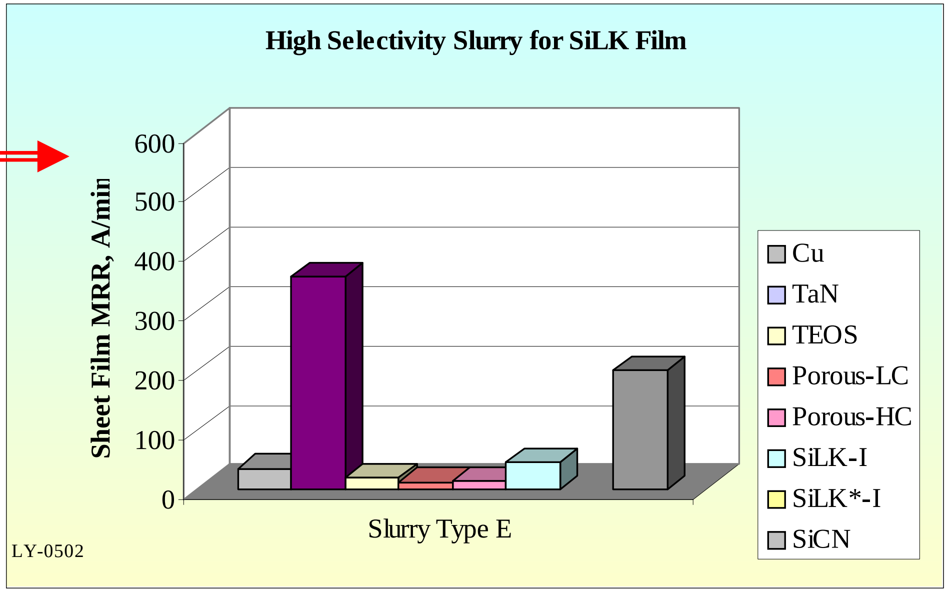
70 rpm carrier speed, 200 ml/min slurry flow

with no conditioning in between wafers

Tunable Selectivity

Silica Based Slurry for High Selectivity Application





Target: Lower SiLK Film MRR

* Original high selectivity slurry (Type A, **pH 4**) shows a higher porous SiLK MRR

* Slurry Type E (**pH 8**) reduced porous SiLK MRR efficiently.

Process Set up: IPEC 472 Polisher / Politex Embossed Pad

Process: **2 psi** polishing pressure, 70 rpm platen speed,75 rpm carrier speed, 200 ml/min slurry flow.

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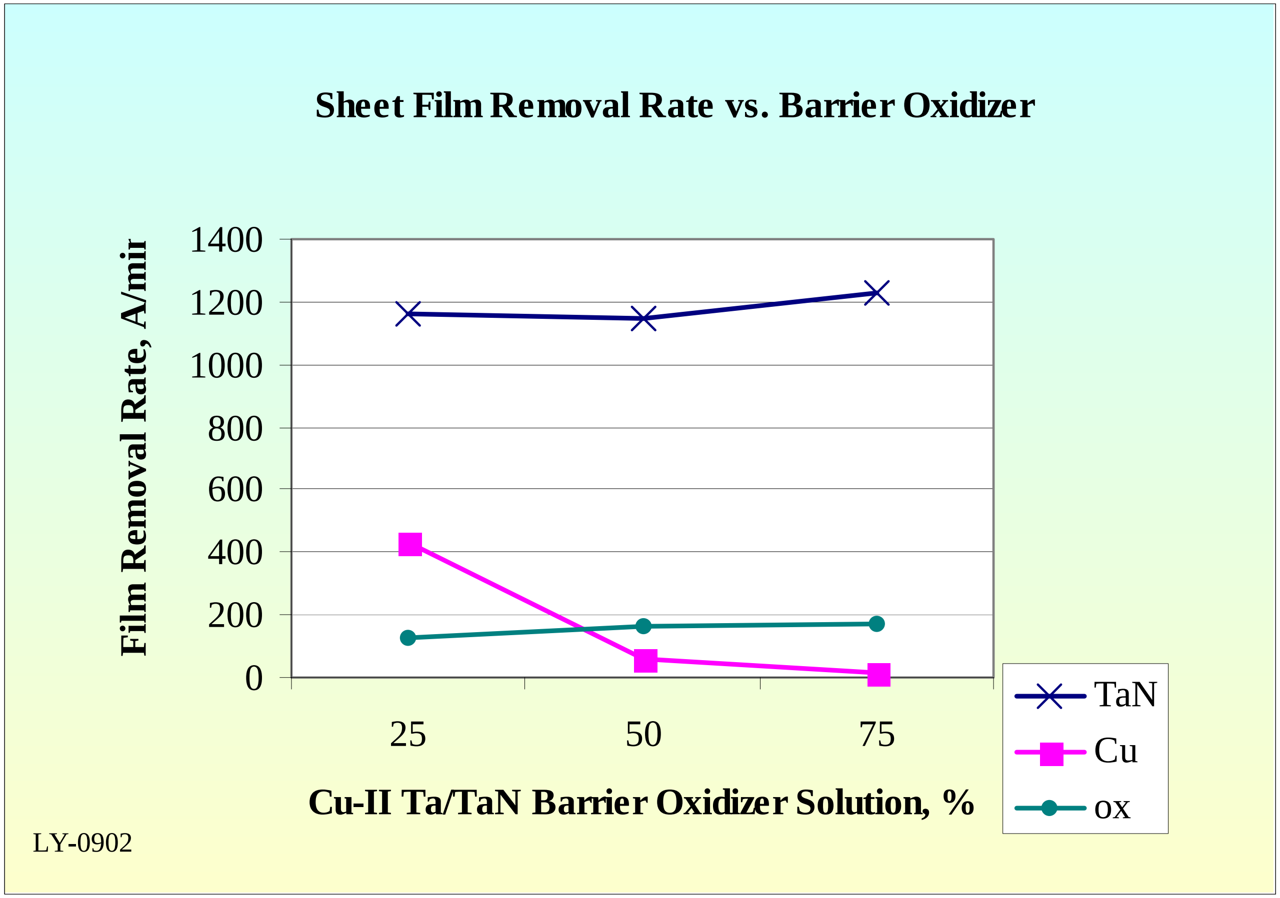
High Selectivity: Blanket Film Application (Politex pad with Slurry C)



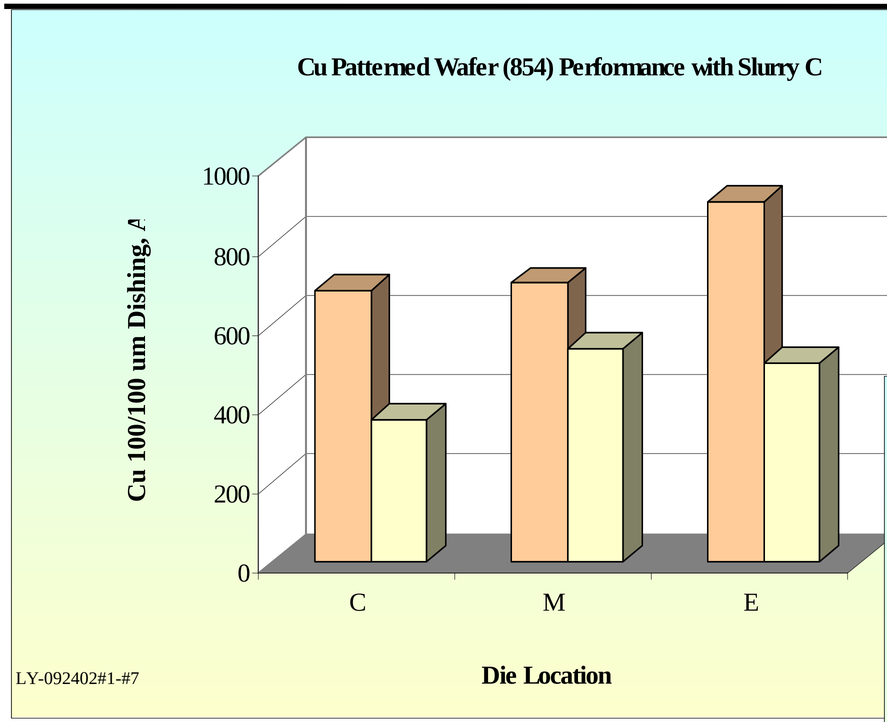
Results:

- TaN and TEOS removal rate was no change.

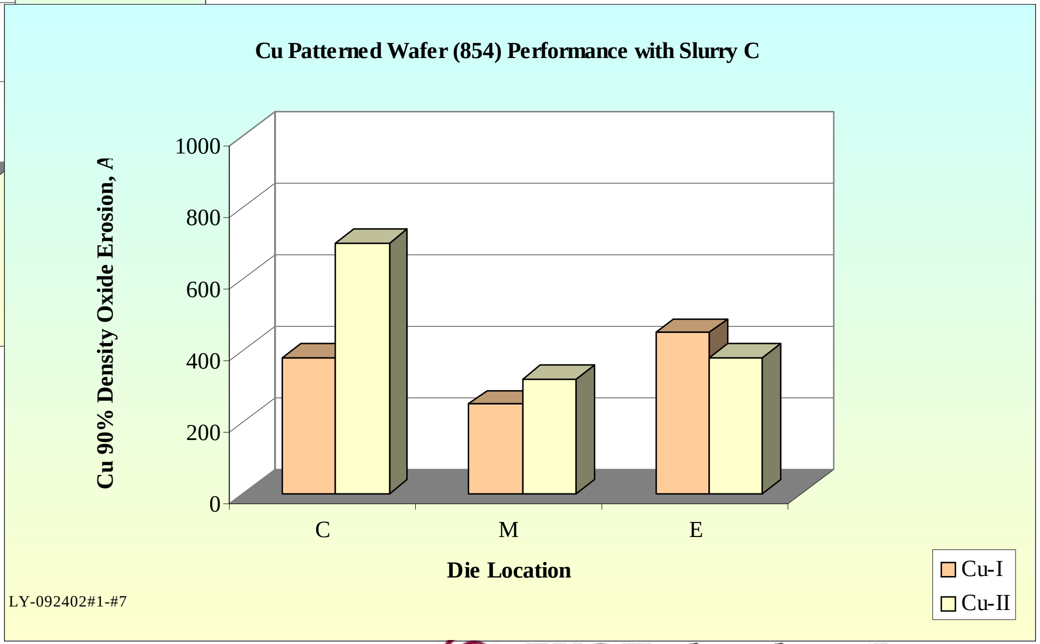
- Cu removal rate reduced while increasing oxidizer solution %

Process:
2psi/90rpmts/95rpmcs/200sf

High Selectivity: Cu Patterned Wafer (854) Application (Politex pad with Slurry C)



Average			
Dishing (A)		Erosion (A)	
Cu-I	Cu-II	Cu-I	Cu-II
764	465	360	467



- First step Cu patterned wafer was polished on OEM tool

- Barrier was polished on EKC IPEC 472

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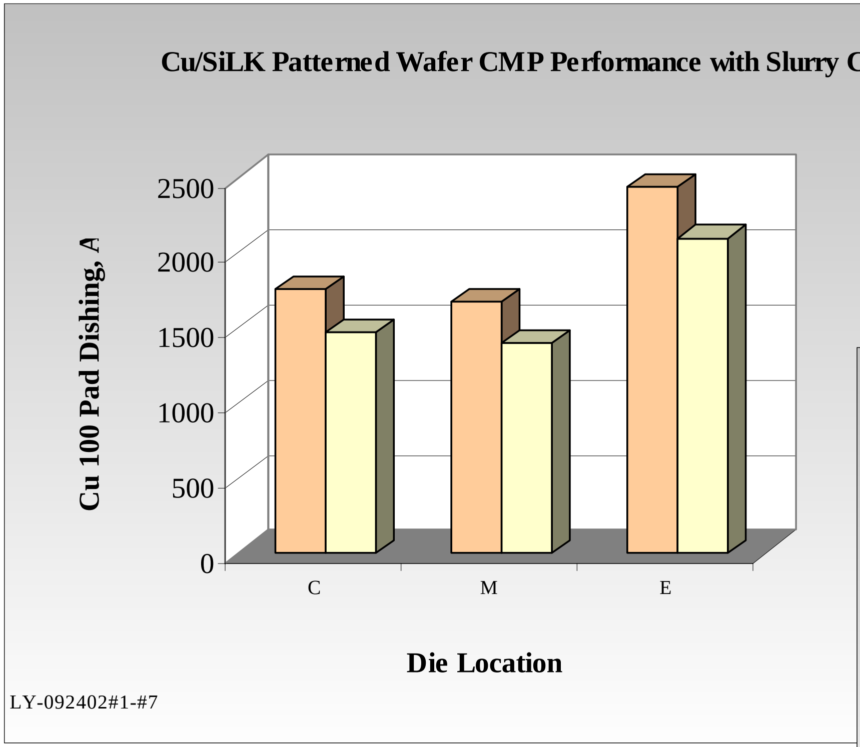
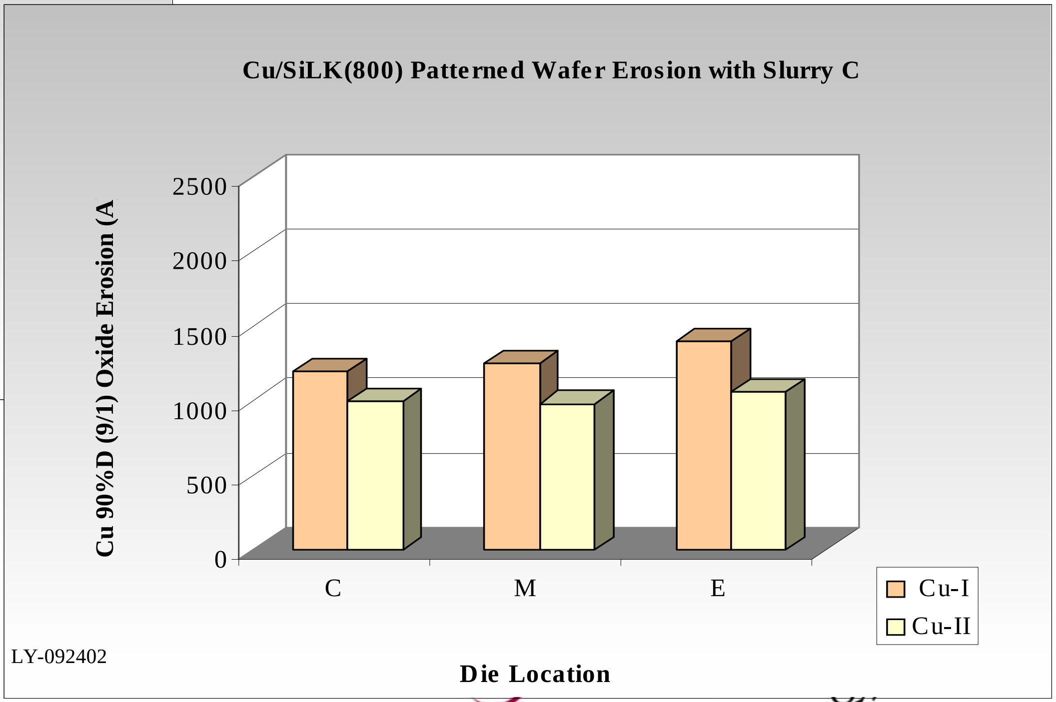
High Selectivity: Cu/SiLK Patterned Wafer (800) Application (Politex pad with Slurry C)



Average			
Dishing (A)		Erosion (A)	
Cu-I	Cu-II	Cu-I	Cu-II
1959	1657	1283	1013



- Cu Film: EKC Cu Phase-I Slurry on EKC 472

- Barrier Film (TaN): Slurry C

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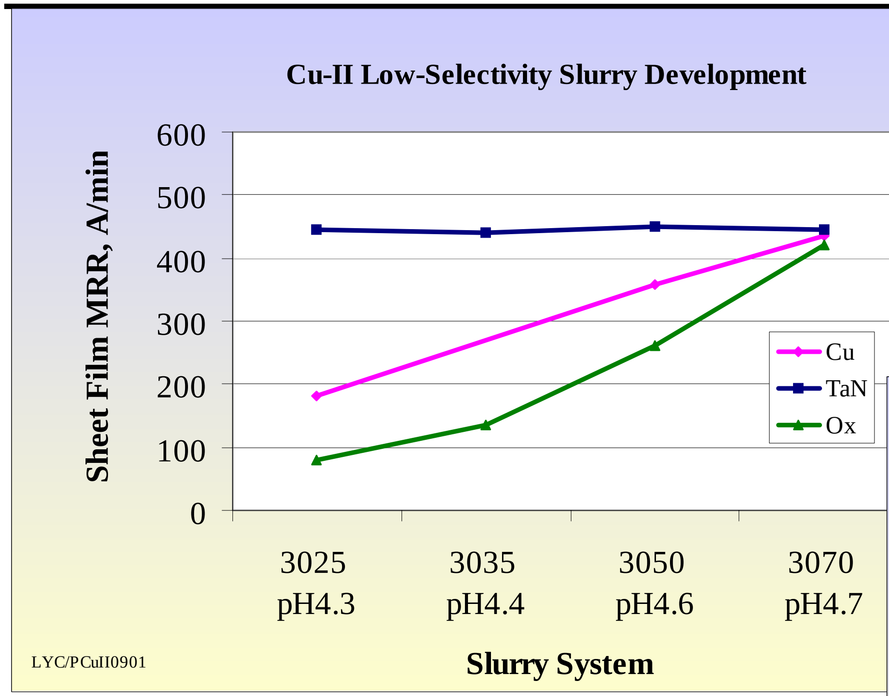
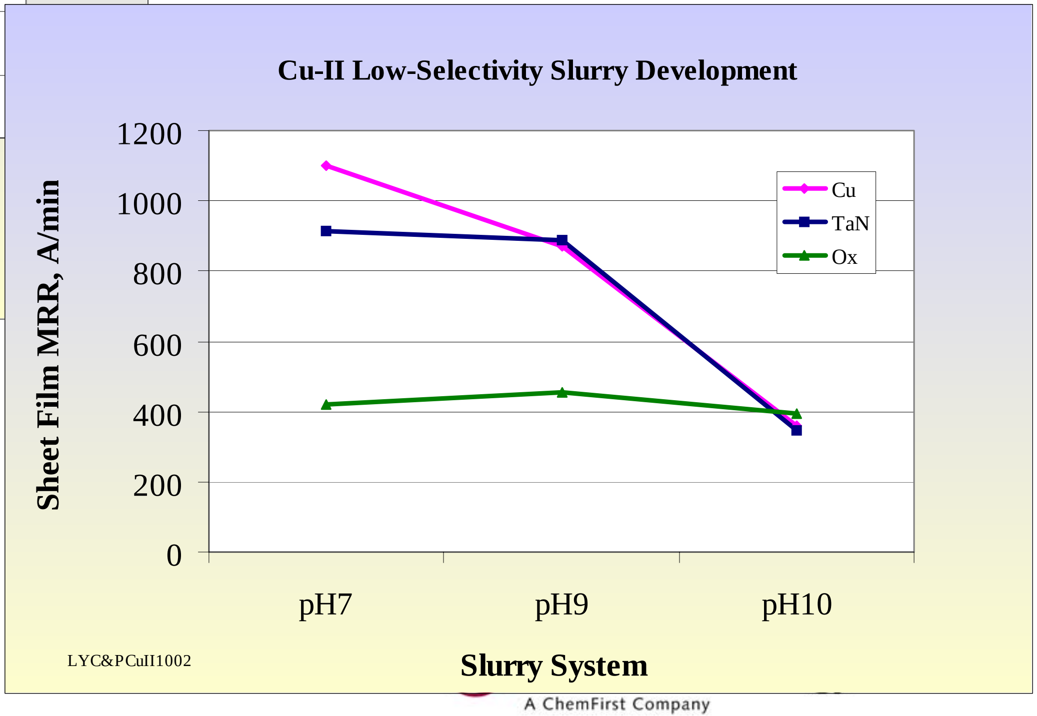
Low Selectivity Barrier Slurry for Cu CMP:

Effect of Concentration and pH





- Hydroxylamine oxidizer
- Colloidal silica abrasive
    - Tuning chemical components
    - Adjusting pH

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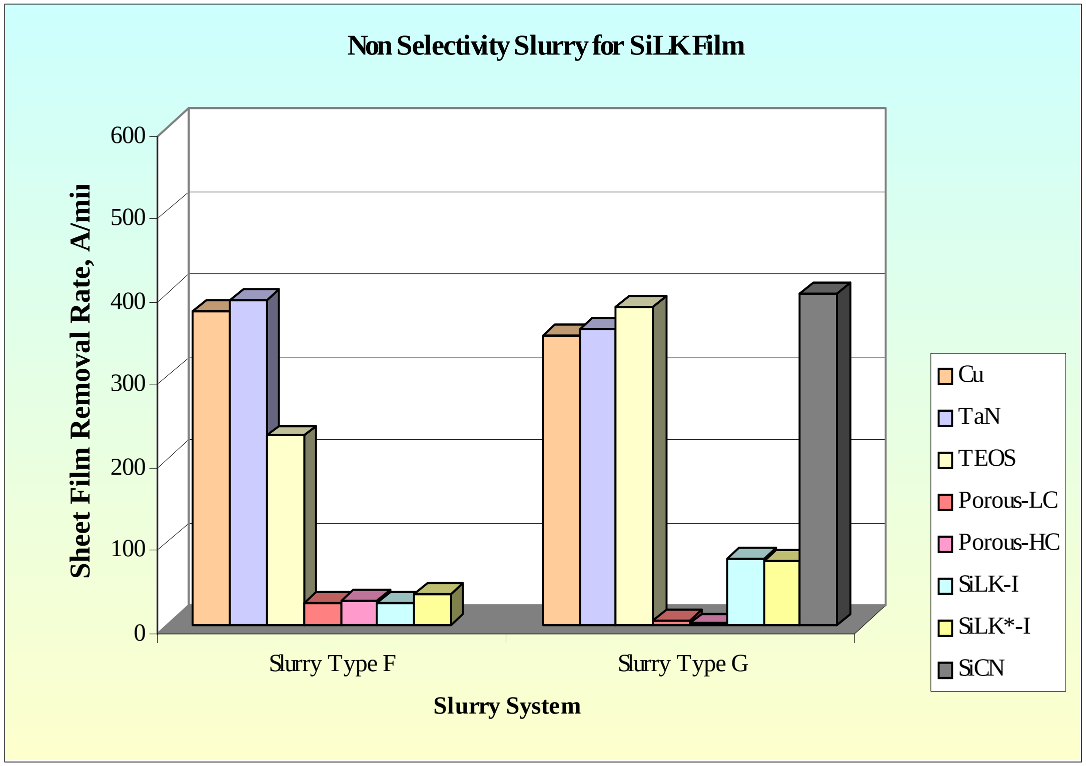
Silica Based Slurry for Low Barrier Selectivity



Results:

Low Selectivity slurry (Type C and D) showed similar TaN MRR to Cu and Oxide.

They also showed a good control for SiLK porous film as well as regular SiLK film.

SiCN MRR is similar to oxide

Process Set up: IPEC 472 Polisher / Politex Embossed Pad

Process: **2 psi** polishing pressure, 70 rpm platen speed

75 rpm carrier speed, 200 ml/min slurry flow

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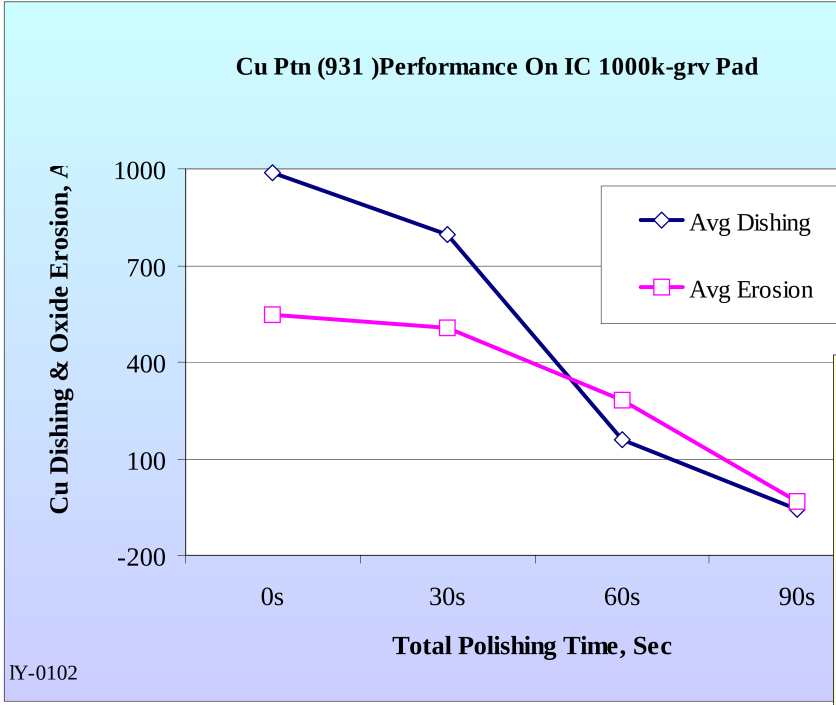
Low Selectivity: Cu Patterned Wafer (931) Application (Different Pads with Slurry F)

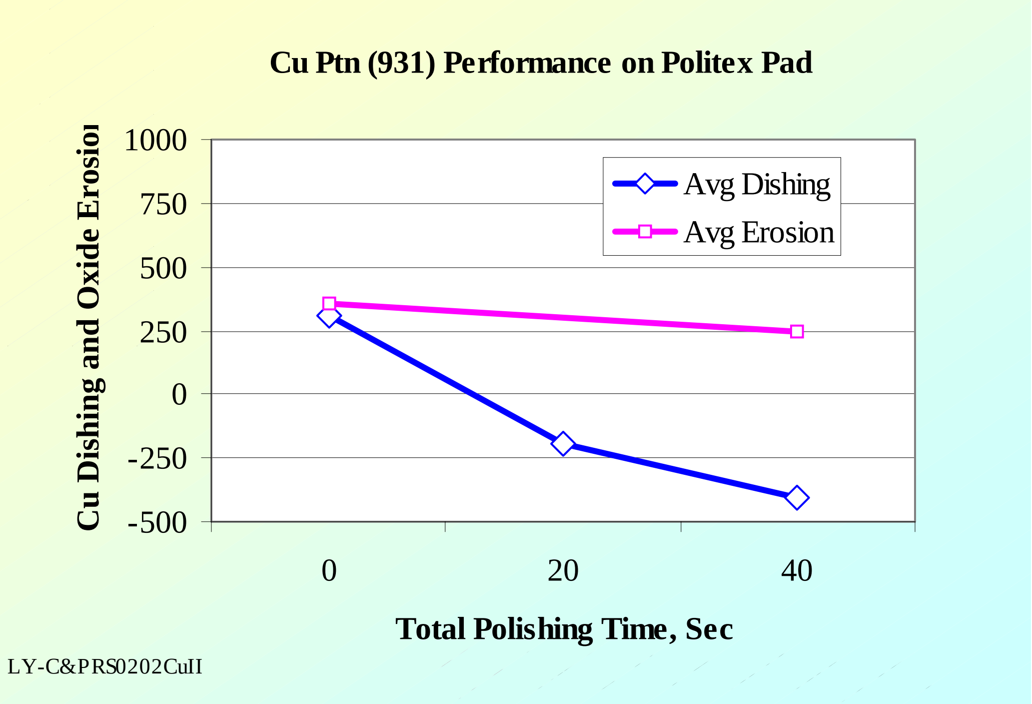


IC1000 K-grv Pad

- First step Cu patterned polished on OEM tool
- Barrier was polished on EKC IPEC 472

Process: **2psi**/90rpmts/95rpmcs/175sf

Politex Pad



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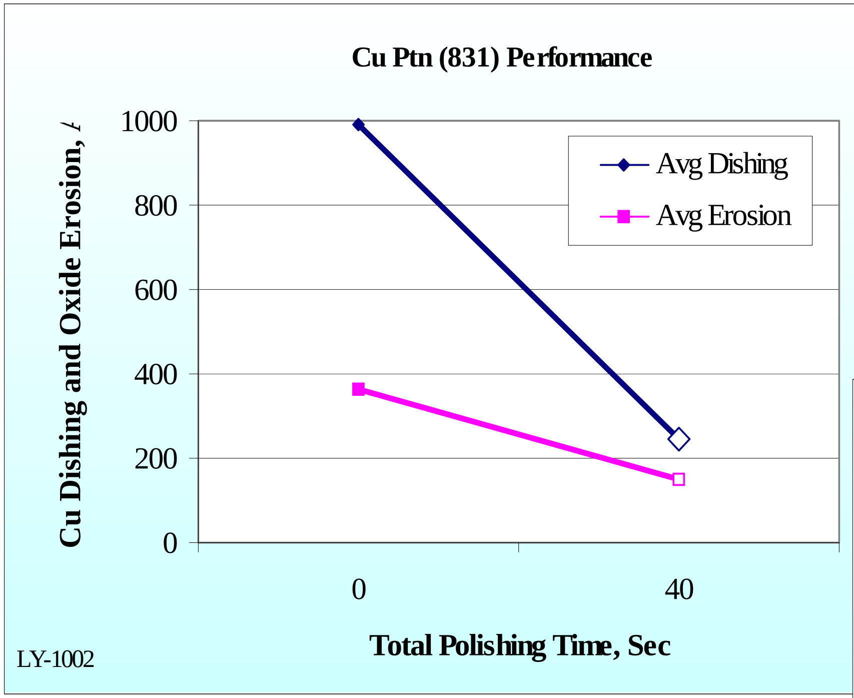
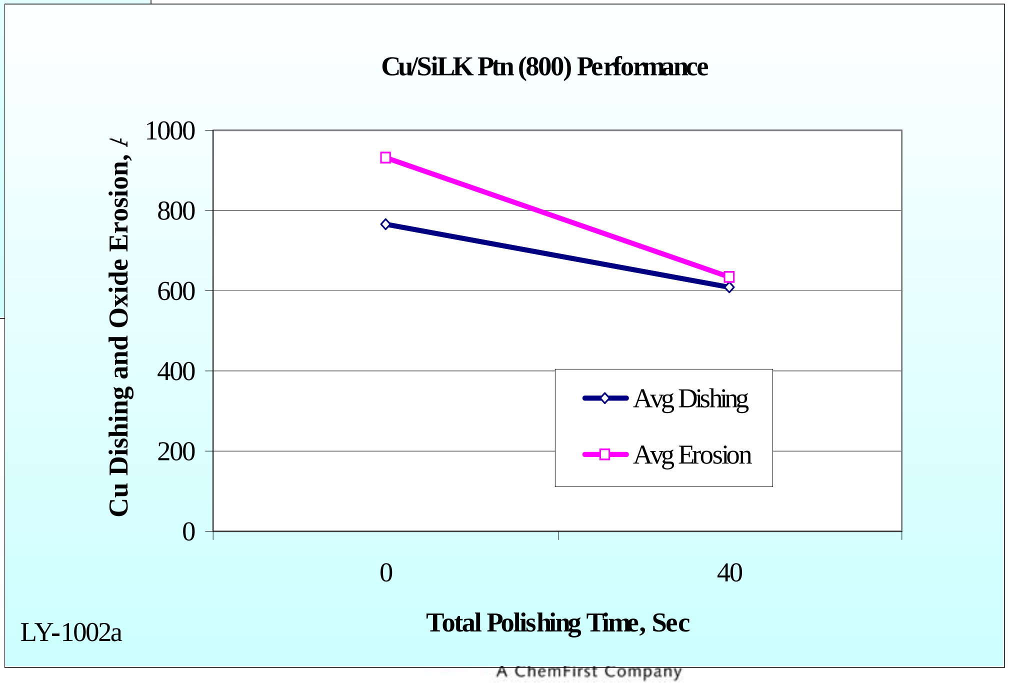
Low Selectivity: Cu Patterned Wafer (831&800) Application (Politex Pads with Slurry F)



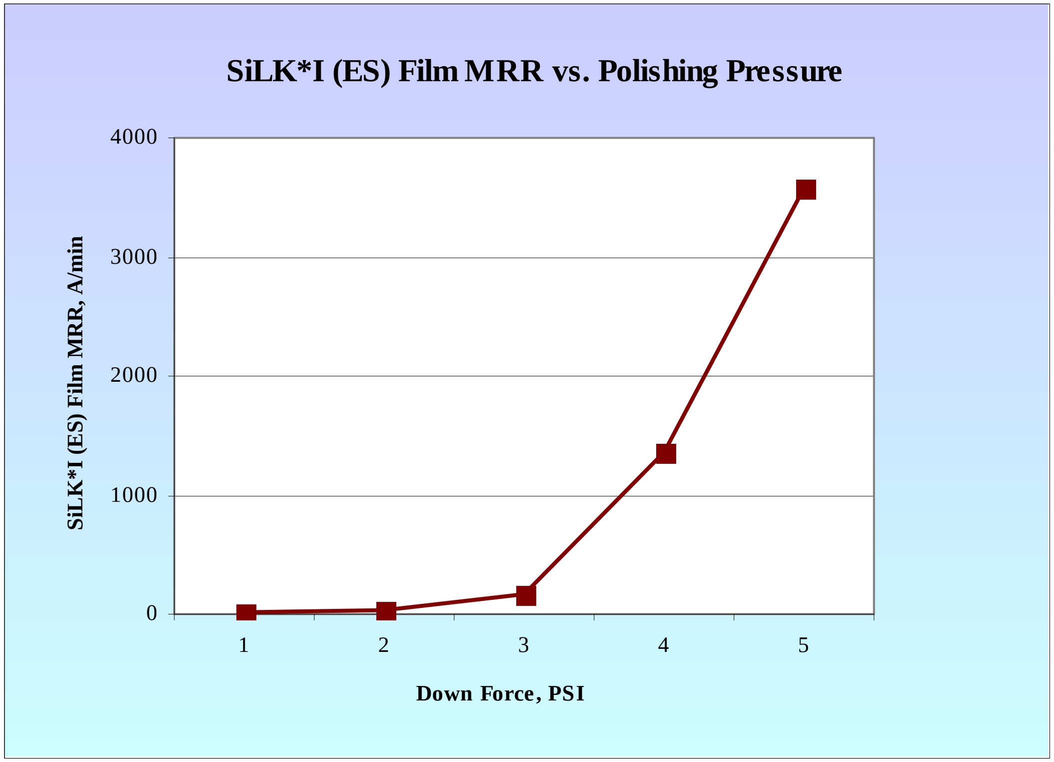
Sematech Cu 831 Patterned Wafer

Sematech Cu/SiLK 800 Patterned Wafer



- First step Cu Film: EKC Cu Phase-I Slurry on 472
- Barrier Film (TaN): Modified Slurry F

SiLK*I (Ensemble) Film MRR vs. Polishing Pressure



Polishing Pressure (PSI)	**Removal Rate (A/min)**	**SiLK*I (ES) Rem NU %**
1	15	n/a
2	40	n/a
3	174	
4	1367	15.8
5	3576	6.5

Other Parameters
IPEC472 polisher
Politex reg pad
90 rpm pp
95 rpm cs
200 ml/min sf

Slurry Type F

No delamination of the films seen at any polishing pressure

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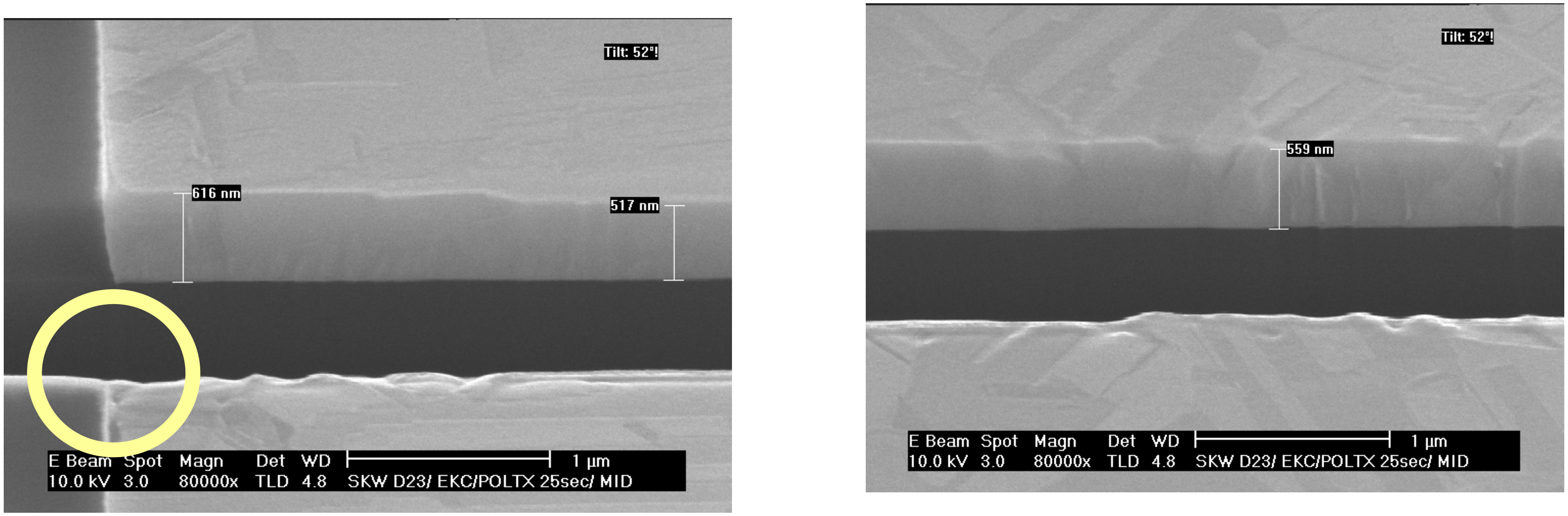
Cross Section of 100-µm Cu Lines after Ta Removal



FIB cross section shows some topography across the 100 um Cu lines after Politex pad

Sheet Film Properties after CMP

Slurry	**Surface rms (A)**		**Adhesion (Mpa-m$^{0.5}$)**	**FTIR**		
	Cu	SiLK	SiLK	SiLK	P-SiLK	SiCN
A	9.5	6.5	0.45±0.02	Pass	Pass	
B				Pass		
C	7.5	7.0		Pass		
D	7.0	5.8		Pass		
E			0.43±0.03	Pass	Pass	Pass
F	8.0	6.5	0.42±0.02	Pass	Pass	
G			0.45±0.03	Pass	Pass	Pass

LY-C&PLowkSiLKproperties2002

Cu pre rms > 30 A, SiLK pre rms = 6 A

SiLK toughness adhesion should > 0.35 Mpa-m$^{0.5}$

Post CMP Electrical Data for P-SiLK (v9)

Dielectric Data	Slurry A	Slurry E
Average k value	2.51	2.37
Electronic Date (avg)		
Breakdown voltage@ J=1e-5 A/cm^2	3.27	3.63
Leakage current at 0.5MV/cm =	3.35E-09	1.09E-09
Leakage current at 1.0MV/cm =	8.54E-09	2.28E-09

LY-C&PLowkSiLKproperties2002

- Breakdown voltage and leakage current looks good for slurry E
- There was a change in low-k value for slurry A
- Leakage current and breakdown voltage for slurry A are different than slurry E.

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Conclusion:

* Hydroxylamine-based slurry is effective for the Cu/SiLK CMP processing.

* With silica abrasive, the slurry can be designed for either high selectivity or low selectivity of Cu/TaN/SiLK integration.

* No delaminating of SiLK films.

* SiLK surface rms and chemical composition were the same as pre-CMP.

* Film removal uniformity and wafer profile are within the spec.

* The new nitrogen-based slurries have the potential to reduce the COO.

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